# REPORT

UPON

# SOME OF THE RECENT RESEARCHES IN NEUROPATHOLOGY.

BY

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# Analyses and Extracts of Original Papers.

## I.

## REPORT UPON SOME OF THE RECENT RESEARCHES IN NEUROPATHOLOGY.

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THE pathology of the nervous system, more than that of any other, is intimately related to its physiology. Indeed, the modern physiological researches and discoveries in the domain of the nervous system have exercised a great bearing upon neuropathology. On the other hand, the neuropathological phenomena have often been applied with great advantage as illustrations and tests for the correctness of physiological facts. The reader of these pages, therefore, will not be surprised at the absence of lines of demarcation between neurophysiology and neuropathology.

Until quite recently, it has been unanimously accepted by the greatest authorities, that the cerebral hemispheres, especially their cortical substance, are only the seat of the psychical sphere, and are absolutely destitute of irritability, though it has always been conceded that for the nerves, irritability (the property to react by their specific energy against stimuli, mechanical, chemical, electrical) is an indispensable vital condition.

The assumption of the absolute want of irritability of the cerebral hemispheres was based upon the results of experimental researches of Longet,* Magendie,† Matteucci,‡ Eduard Webber,‖ Budge,§ Schiff,¶ and others.

These great physiologists had irritated the cerebral hemispheres of living animals mechanically, chemically, electrically, without succeeding to call forth muscular contractions. Van Deen went so far as to deny the irritability to all the nervous centres. But the strongest arguments against the existence of irritability in the cerebral hemispheres were derived from Flourens's** celebrated experiments. From the result of removing the cerebral hemispheres he concluded that they are not the seat of the immediate principle (*principe immédiat*) of muscular movements, but only the seat of volition and sensation.

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* Longet. Anatomie et physiologie du système nerveux de l'homme et des animaux vertébrés. Paris, 1842. T. I., p. 643. "On peut irriter les lobes cérébraux mécaniquement, chimiquement, galvaniquement, chez les animaux sans donner lieu a des secousses convulsives."

† Leçons sur les fonctions et les maladies du syst me nerveux. Paris, 1839.

‡ Matteucci. Traité des phénomènes électro-physiologiques des animaux. Paris, 1843, p. 242.

‖ Ed. Webber, in R. Wagner's Handwörterbuch der Physiologie. Bd. III.

§ Budge. Untersuchungen über das Nervensystem. Frankfurt a. M., 1842.

¶ Schiff. Lehrbuch der Physiologie des Menshen. 1859, p. 362.

** Flourens. Recherches expérimentales sur les propriétés et les fonctions du système nerveux dans les animaux vertébrés. Paris, 1842, p. 35.

The experimental researches, an account of which I present in this paper, mark an epoch in the history of the physiology and pathology of the brain. Made independently by several investigators, and with entirely different methods, these remarkable researches have led to an identical result, contrary to the one obtained by the former investigators, viz.: that the cortical substance of the cerebral hemispheres is in close relation to certain muscular groups (psychomotor centres of Gudden).

The starting-point for the researches of Fritsch and Hitzig * was the fact observed by Hitzig that contractions of the eye-muscles can be produced in the living man by the galvanic excitation of the hemispheres. This fact being entirely in opposition to the generally adopted theory of the want of galvanic excitability of the hemispheres, Fritsch and Hitzig instituted the following experiments. Having removed in dogs a portion of the dura mater (which was found extremely sensitive) and of the pia mater (which is not at all sensitive), the cerebral hemispheres were irritated with an extremely weak galvanic current. By intercalating a rheostate as an accessory current, they were enabled to experiment with great precision and with all the precautions necessary for exact scientific researches.

They found that the excitation of distinct and limited localities (centres) of the anterior convex portion of the brain produces movements of certain muscular groups on the opposite side of the body, whilst the same excitation of portions of the hemispheres, situated more posteriorly, produced no such effect. Thus they found the centre for the muscles of the nape of the neck situated in the middle of the præfrontal convolution (gyrus præfrontalis): the centre for the extensor and adductor muscles of the anterior extremity at the external end of the postfrontal convolution; and somewhat behind, the centre for the flexor and rotation muscles of the same extremity. The centre for the muscles of the posterior extremity is also situated in the post-frontal convolution, but more behind and towards the median part than the centre for the anterior extremity. The muscles, innervated by the facial nerve, are controlled by a centre located in the middle portion of the supersylvian convolution. The irritation of these centres by metallic closing of a galvanic current of minimal intensity will call forth a single contraction of the corresponding muscles on the opposite side, whilst tetanizing currents will produce tonic and gradually disappearing contractions of these muscles, followed by epileptiform movements. A very remarkable phenomenon is noticed in these experiments, viz.: the predominant effect of the anode. Unlike the nerves, the cortical cerebral substance is easier excited by the anode than by the cathode, and if the current be of a minimal intensity, the contractions can be produced only by the anode. On placing the anode on one centre and the cathode on another, only those muscles will contract whose centre is under the influence of the anode, and no contractions will take place if the anode, not the cathode, be moved away from the centre.

That the muscular contractions were produced by the excitation of the centres situated in the cortical substance, and not by current loops affecting the central terminations of the motor nerves, is proved by the minimal intensity of the employed current, by the extremely small distance between the electrodes, by the great resistance of the brain-substance, by the appearance of the contractions only on the opposite side of the centres, by the cessation of the contractions at the least shifting of the electrodes, and, when the irritability of the brain is rapidly abolished, by

* Fritsch und Hitzig. Ueber die electrische Erregbarkeit des Grosshirns. Reichert and Dubois-Reymond's Archiv. 1870, p. 300.

hæmorrhage. Immediately after the death of the animal the irritability of the brain is entirely extinguished, and no contraction of the muscles can be obtained by the galvanic excitation of the described centres; but the irritability of the nerves and muscles remains perfectly intact for some time after death, and contractions, therefore, could have been called forth, had they been produced by current loops exciting the central terminations of the motor nerves. Fritsch and Hitzig have given, besides, a direct demonstration of the above assumption.

By introducing Carlsbad needles, which were isolated except their points and heads, into the posterior parts of the hemispheres, not a trace of contraction could be produced, though the employed current was much stronger than the one used for the excitation of the centres. They proved also that the contractions are produced by a direct excitation of the centres and not through reflex action. The reflex convulsions produced by irritation of the dura mater, for instance, are of an entirely different character than the localized muscular contractions, following the excitation of the cortical centres, in one limb or one group of muscles on the opposite side, and ceasing altogether as soon as the electrodes are moved away from the centres. When Fritsch and Hitzig removed in dogs the centre for the muscles of the anterior extremity, this latter did not become entirely paralyzed; the animals could use it, but imperfectly, and seemed quite unconscious of the condition of the limb, which could be placed into the most uncomfortable position without attracting their attention. There must therefore exist another conducting way from the psyche to the muscle, whereas the conduction from the muscle to the psyche must have been interrupted at the above centre.

It may be asked why former investigators, among whom are the most brilliant names, obtained contrary results. This is explained by the superiority of Fritsch's and Hitzig's methods. Their predecessors, penetrated by the idea of the presence of the psychical functions in all the parts of the cerebral hemispheres, contented themselves with examining only those parts of the cortex which are easier accessible in vivisections, viz.: the lateral and posterior portions of the hemispheres. They would have arrived at contrary results had they admitted of a localization of the psychical functions, and not drawn a conclusion for the whole convex surface of the brain from experiments on the posterior or lateral parts.

The experimental researches of Fritsch and Hitzig may be thus summed up: In the anterior part of the cortical substance of the cerebral hemispheres (in dogs) exist certain centres which are indispensable for the production of muscular movements. Electrical irritation of these centres calls forth contraction of certain groups of voluntary muscles, their destruction inhibits these voluntary movements. (Compare abstract of J. Hughlings Jackson's paper, p. 490. [EDITOR.])

The Franco-German war afforded Hitzig * the opportunity of demonstrating the existence of the motor centre for the facial nerve also in man. A French soldier who received a wound in the right side of the head, causing a circumscribed abscess in the anterior central convolution, was attacked with spasms followed by incomplete paralysis in the sphere of the facial nerve, on the opposite side.

The experiments made on dogs by Fritsch and Hitzig are also corroborated, with reference to human pathology of the brain, by observations made during the Prusso-Danish war and collected and edited by Löffler.† The gun-shot injuries of

* Hitzig. Ueber einen interessanten Abscess der Hirnrinde. Archiv für Psychiatrie und Nervenkrankheiten. 1872. Bd. III., H. 2, p. 231.

† Löffler's Generalbericht über den Gesundheitsdienst im Feldzuge gegen Dänemark. Quoted by Simon. Berlin. klin. Wochenschr. 1873, No. 4.

the brain, in some respects, resemble those produced by the experimenter. The organ is attacked in its healthy condition, and the employed force is so sudden and so intense that the injury is often limited to the part of the skull that was touched and to the corresponding portion of the brain.

The gun-shot injuries of the hemispheres have to be classified into two distinct categories. Injuries produced by bullets entering more transversely and affecting the lateral portions of the hemispheres (temporal lobes), and those where the bullets enter in an antero-posterior direction and injure the convexity of the hemispheres. The statistical tables show a striking difference between these two categories of injuries of the brain as regards their symptoms and termination. The injuries of the temporal parts produce no paralytic symptoms, but a comatose condition, and generally terminate fatally. The injuries of the convex portion of the brain always produce a paretic or paralytic condition of one or both extremities on the opposite side, generally without sopor, and are often followed by recovery.

Thus even these observations, though hastily made on the battle-field, still tend to prove that in man also there exist motor centres for the extremities in the cortex of the cerebral hemispheres.

Nothnagel's* experimental researches on the functions of the brain are made mostly on rabbits, and by means of a new method introduced by him.

The oldest and most frequently employed method of experimenting presents very great disadvantages. It consists in the removal of a part of the skull and of portions of brain-substance. This method, therefore, causes hæmorrhages, refrigerates the brain, and changes the intracranial pressure, and does not admit of the removal of very small portions of the brain. Again, the mammalia die within the first twenty-four hours after the removal of the cerebral hemispheres, the corpus striatum; and the experiments of Nothnagel have shown that, as a rule, the symptoms appearing in the first hours after the operation are of no great value. Another method, formerly employed—to introduce a small knife through an opening in the bone, and produce sections of certain portions of the brain—had also great disadvantages. In the first place, it could be used only for certain regions of the brain, and caused intracranial hæmorrhages, which obscured the result of the experiment by the symptoms of compression, and offered great difficulties for determining the extent of the section.

Nothnagel's method is as follows:—A simple incision is made on the rabbit's head; the skull is perforated with a needle fixed to a handle (like those in use for microscopic examination, but very much shortened so as not to penetrate into the brain). Through this canal in the bone a minimal drop (about $\frac{1}{4}$ or $\frac{1}{2}$ of a medicinal drop) of concentrated chromic acid is injected by means of a hypodermic syringe with a silver canula, having the thickness of a fine needle. The cutaneous wound is then united by a suture. This operation is easily performed without any assistant; the rabbit, not even being tied, keeps quietly on the table, and shows no signs of pain, except at the sewing of the wound. After the operation nothing particular can be noticed in the appearance of the animal, except the functional derangement incidental to the lesion. Generally the animals live two or three weeks, seldom only a few days, and never more than three weeks. They appear healthy, sometimes become emaciated until they are found dead. Nothnagel could not ascertain the cause of death. It seems singular that such a minute

* Experimentelle Untersuchungen über die Functionen des Gehirns. Virchow's Archiv, Bd. 57, Heft II., p. 184.

circumscribed foyer in one hemisphere should cause it. No cheesy processes are found in the lungs, no affections of the intestinal canal; and it is quite improbable that the very small quantity of the chromic acid that remains encapsulated should have any poisonous effect.

In one exception the operation is followed by immediate death; it is when the chromic acid is injected into one of the lateral ventricles, whence, through the foramen Monroi, it enters into the third and fourth ventricles, which calls forth dyspnœa, general convulsions, and death.

These experiments with an immediate fatal result, of course, have not been taken into consideration.

In the successful experiments the following is found at the autopsy: A minute circumscribed place, where the chromic acid was injected, appears of a green color, resistant and hard. If the animals survive the operation for a considerable time, a thin yellowish encephalitic zone develops itself around the circumscribed lesion (foyer). When the injection was made not on the surface of the brain, but in its interior, the trace of the canal above the chromic acid lesion can be noticed.

The advantages of this method are obvious. The hæmorrhage and exposure of the brain surface are entirely obviated. The intracranial pressure, though at first somewhat changed by the access of air through the small canal, becomes normal at the closure of the communication. The animals survive a considerable length of time and admit of a continued observation. This is so much the more important, since Nothnagel has shown that many morbid phenomena which appear during the first five hours after the operation entirely disappear afterwards. They are caused by the operation, by its producing a change in the intracranial pressure and in the circulation, and disappear when the immediate effect of the operation has ceased and the normal conditions are reëstablished. Only the functional derangement caused by the circumscribed cerebral lesion remains more permanently. This shows how careful we have to be in explaining the morbid phenomena observed with methods where the animals die soon after the operation. Nothnagel's method affords the possibility of producing at a given time and in a given locality a small circumscribed organic lesion, with which only by chance we occasionally meet at post-mortem examinations. By means of the above method Nothnagel made a circumscribed chromic acid lesion on the surface of the cortex which penetrated into its substance about one millimeter deep, in a certain limited locality, corresponding exactly to the external end of the post-frontal convolution (Fritsch and Hitzig's centre for the muscles of the extremities in the dog).* The animals appeared to be perfectly healthy during many days after the operation. Their locomotion and appetite were quite natural, and the cutaneous sensibility perfectly normal. A more careful observation, however, revealed a very interesting phenomenon. The animals had lost the muscular sense in the anterior extremity on the opposite side to the cerebral lesion. The affected paw could be put into the most unnatural and uncomfortable position, and remain so for several minutes, while the animal would frustrate any attempt at handling the other paw in a similar manner. This condition remained from six to twelve days, after which it became less distinct and finally disappeared, the animals then presenting nothing abnormal until death. In the same way Nothnagel produced the loss of the muscular sense in dogs, in which the effect upon the posterior extremity by injuring the corresponding centre is still more marked than in rabbits. The movements of the affected extremity present a very characteristic symptom of ataxia.

* The brain of rabbits does not possess any convolutions.

The described phenomenon can be called forth only by producing the lesion in the above-named limited locality, but in no other place. In this locality, therefore, must be situated a central station for the passage of the peripheric sensitive impressions which are produced by the different positions of the limbs. From the fact, however, that after a certain time the animals recover the lost muscular sense, Nothnagel concluded that the terminal station, or the real centre for the muscular sense, must still exist elsewhere, and that in the above locality was destroyed only an intermediate station in the tract of the muscular sense. After a while, however, other ways become opened for the passage of the muscular sense.

The characteristic phenomenon of ataxia produced in dogs by the lesion is in perfect accordance with the theory of Leyden. This distinguished clinicist does not admit in locomotor ataxia an affection of the centre of coördination in the spinal cord, but assumes that the morbid process of the cord merely interrupts the conducting ways to the coördination centres, which are located in the brain.

Nothnagel found further a circumscribed locality in the cerebral cortex, the lesion of which produces hemiplegia of the opposite extremities (a cerebral hemiplegia is always incomplete in quadrupeds, especially in rabbits).

The chromic acid lesion that produces this effect occupies a very distinct and limited place in front of that for the muscular sense, not, however, on the convex surface of the cortex, but entirely on its lateral side, and penetrating about one or one and a half millimetres into the cortical substance. The cutaneous sensibility remains intact. In the first days or hours a manége-mouvement occurs occasionally in an opposite direction to the lesion. The hemiplegia, like the above-mentioned loss of muscular sense, continues for about six or twelve days, when it gradually disappears, and in about fourteen days the animals entirely regain their healthy appearance in all respects.

This affection, therefore, presents a perfect analogy with that of the muscular sense, in regard to the clinical history, the anatomical lesion, and the explanation of the morbid phenomena. In both cases the affection is produced by a destruction of a peripheric layer of the cerebral hemisphere in a certain limited place, and in both the functional derangement disappeared by degrees. The inference to be drawn from both cases is, therefore, entirely the same. Unlike Fritsch and Hitzig, Nothnagel assumes that the above localities in the cortex are not the terminal centres of the nerves which conduct the excitation from the will to the muscular groups, but that they are merely intermediate stations, and that other conducting ways may transmit, in a vicarious manner, the commands of the will to the same muscles. Nothnagel failed, however, to demonstrate that the restoration of the functional derangement is not due to a compensatory activity of the not destroyed homologous parts of the other hemisphere. The animals invariably died soon after he produced a lesion in the corresponding parts of the other hemisphere.

In no other portions of the cerebral cortex, except the above-mentioned, have the chromic acid lesions been followed by paralytic symptoms.

According to the experiments of Flourens, Longet, and Schiff, no paralysis can be produced in the lower animals by partial lesions, or even by the removal of a whole hemisphere. Nothnagel, on the contrary, demonstrated the existence in the white substance of the cerebral hemispheres of certain localities a lesion of which will invariably produce paralysis on the opposite side. The place more especially endowed with this property is the white substance surrounding the cornu ammonis.

Very interesting are also the effects produced by the chromic acid lesions of the great cerebral ganglia. A lesion of the nucleus lenticularis invariably produces paralysis of the opposite extremities, and a lateral curvature of the spine. This scoliosis affects the whole vertebral column, the convexity of the curvature being always on the opposite side to the cerebral lesion.

The mechanism of the lateral curvation needs no further explanation; it is evidently produced by the paralysis of the muscles of the trunk on the opposite side to the lesion. Like all the above-mentioned affections, this also gradually disappears, though more slowly, if the animals survive the operation for any length of time. No alteration of the cutaneous sensibility has been noticed. The result of these latter experiments is not in accordance with human pathology. It has been asserted by some authors that lesion of the nucleus lenticularis is followed by paralysis of the extremities only, but not of the muscles of the opposite side of the trunk, and that they are accompanied by anæsthesia. These assertions therefore will have to be verified by new observations.

With regard to the nucleus caudatus, Nothnagel has confirmed the much disputed result of Magendie's experiments, which he gives in a more precise and modified form. By producing a lesion of a minimal extent in a distinct point of the nucleus the animal is attacked by an irresistible tendency to run forward. If it meets a wall or any other impediment it turns and continues to run until, after five or eight minutes, it falls exhausted upon the side, still continuing to make forward movements with the extremities. If raised up it runs again some distance until it falls. This the animals repeat several times during half an hour or more, after which they remain quietly in a condition of perfect apathy and exhaustion. They never survive the operation more than twelve or eighteen hours. Nothnagel calls this distinct point, the lesion of which produces the described phenomenon of running forward, nodus cursorius (running knot). This point is situated in the middle of the nucleus caudatus near its free margin towards the ventricle. The chromic acid lesion of any other part of the corpus striatum, even including the nodus cursorious, is always followed by paralysis on the opposite side, without the above-described tendency to run forward.*

The experimental researches on the nervous system by Gudden† are highly important and interesting. He has experimented on new-born animals (mostly rabbits), the first or second day after birth, kept them alive a considerable time in order to study the effect of these lesions of the nervous centres in the grown-up animals. The younger the animals, the more striking the subsequent effects. The experimental operations and their results are very much promoted by the following peculiarities of the young animal: by the undeveloped state of sensibility, the absence of hair, the great coagulability of its blood, and the extraordinary rapidity of its growth.

The young animals offer no resistance to the cutting instruments, but with every postponed day increases the sensation of pain, and consequently the resistance. The rapidity with which the blood coagulates in the young animals is extremely favorable for these experimental researches. Even when large vessels are injured,

* After the completion of Nothnagel's researches, Beaunis published his method of making injections into the brain, in the *Gazette Méd.*, 1872. He, however, obtained no satisfactory results, owing probably to the large quantities injected or to the selection of improper substances.

† Experimentaluntersuchungen über das peripherische und centrale Nervensystem. Archiv. für Psychiatrie und Nervenkrankheiten. Bd. II., p. 693.

the hæmorrhage is soon arrested spontaneously. Thus portions of brain can be removed in such localities where no ligature can be applied, or where, if applied, it would interfere, as a foreign body, with the result of the experiment. But the greatest advantages from experimenting on new-born animals are derived from the wonderfully rapid healing of the wounds by first intention, without the intervention of any secondary accidents, provided the old animals take care of their young, furnish them with food and warmth, and protect them from being injured by other rabbits. It is astonishing with what immunity the new-born animals undergo the most severe operations, which have no parallel in other vivisections. This is owing to the great energy of tissue-metamorphosis that continues for some time after birth.

The operated animals, being marked with a small excision on the ears, are put back into the nest with the parents, and allowed to live until fully grown, when they are killed by a hypodermic injection of hydrocyanic acid. In experimenting on the brain, Gudden found best not to incise the bones, but to make use of the cranial sutures, so as to separate the bone on three sides, and turn it over like a lid. The incisions in the brain-substance always give rise to profuse hæmorrhage, that soon, however, stops by the rapid coagulation of the blood. After the object of the operation is accomplished, the bony lid must then be carefully put into its former place, and the cutaneous wound sewn together. Until now Gudden published in full only his researches on the olfactory and optic organs, an abstract of which is here given.

Concerning the result of his experiments on the cerebral hemispheres, the following short notice was published in the *Correspondenzblatt für Schweiz. Aerzte*, 1871, No. 4: "Very convincing facts are obtained by removing the cerebral hemispheres in new-born animals, and allowing them to grow up. The result is idiotismus. There is also reason to locate the organic conditions of voluntary movements in the cortical substance of the brain, but there is no reason to accept the corpus striatum as a motor ganglion. The hemiplegia following the destruction of the nucleus lenticularis can be satisfactorily explained by the rupture of fibres passing through the internal capsule. But admitting the cerebral cortex as the organ for voluntary movements, there is no necessity to have another motor ganglion. Indeed, Gudden's experiments on new-born rabbits, by removing portions of the hemispheres, have demonstrated that the organ of voluntary motion is located in the frontal part of the cerebral cortex. . . . . He presented the brain of a grown-up dog, in whom, immediately after birth, he removed those frontal convolutions in which are located the psycho-motor centres. In this specimen, as in those of rabbits in which the superficial layer of the frontal convolutions was removed, can be seen an atrophy of the corresponding (opposite) pyramid of the medulla oblongata. . . . ."

### 1. *Experiments on the Olfactory Organs.*

In the majority of mammalia the olfactory organs play an important part; in some animals especially they serve to the excitation of the sexual and other functions. These organs consist of the nervus olfactorius, bulbus olfact., and tractus olfact., and also of the lobus pyriformis and the commissura anterior, the development of which in different animals is in a direct ratio to the functional activity of the olfactory sense. The olfactory bulbs are independent censory centres, and must, therefore, present a high significance in the doctrine of hallucinations. They communicate with the external world by means of the olfactory nerve and its terminal structures in the olfactory region, and with the hemi-

spheres only by means of the tractus olfactorii. These latter enter into the cortical substance of the lobi pyriformes, which are (*i.e.*, their cortical substance) mutually connected by the anterior commissura.

Gudden closed in a rabbit, immediately after birth, one nasal opening, by cutting off its margin and uniting the wound with sutures. After six or eight weeks the animal was killed, and all the olfactory organs on the operated side were found in a high degree of atrophy, while those of the other side were hypertrophied.

Not only the nervus olfactorius, bulbus and tractus olfact. of the operated side presented considerably smaller dimensions than on the other side; but the cranial covering of the olfactory organs was much thickened on the injured side, and very thin on the other.

The same result is obtained by removing, in the new-born rabbit, the olfactory nerve or the mucous membrane (with the conchæ) of the olfactory region.

After the removal of the bulbus olfactorius, the empty space is found partially taken up by the hypertrophied bulbus of the other side, but mostly by the hemisphere of the operated side. But the most important result of this experiment is the disappearance of the tractus olfactorius, of which only an insignificant trace can be discovered with a loupe.

The lobus pyriformis, in whose cortical substance the tractus olf. enters, is also found atrophied on the operated side.

The innervation of the lobus pyriformis separated from its bulbus takes place through the commissure. Gudden gives numerous illustrations showing the high significance of the commissures which are the real ways of communication between double organs. By the existence of commissures can be explained that after the removal of a whole hemisphere in the new-born animal, it afterwards cannot be distinguished from other animals possessing both hemispheres, either with regard to its voluntary movements, or to its reaction against sensory impressions.

The removal of a whole hemisphere is easily borne by the young animals, especially if performed immediately after birth. They recover very rapidly after the operation.

The removal of both bulbi olfactorii is in itself an easily performed operation and produces a comparatively slight injury. But the young animals, deprived of the olfactory sense, are unable to find the mother's breast, and invariably perish.

Gudden removed the eyes and closed the external auditory meatus in new-born animals. Deprived of their sight and hearing, the animals were obliged to be guided by their olfactory sense, in consequence of which the olfactory organs became very much developed.

Gudden discovered the fact that wherever a portion of brain is arrested in its development, the corresponding cranial bone is very much thickened, and on the contrary, it is very thin over the more developed cerebral parts.

### II. *Experiments on the Optic Organs.*

Gudden produced a permanent closure of the eyelids of one eye in new-born rabbits, by cutting off the margins of the lids and uniting them by sutures. The eyes remain intact under the closed eyelids, and the animals can regain their sight by an operation of separating the lids again. But if, after having had their eyelids closed at their birth, the animals are killed when full grown, the optic nerve of the operated side and the corresponding anterior prominence of the corpora quadrigemina are found atrophied, though not in such a degree as are found the central olfactory

organs after the closure of one nasal opening. It seems that notwithstanding the closure sufficient light penetrates through the lids to excite and preserve the optic apparatus. The effect is more decided when one retina is destroyed or one eye enucleated. One-eyed rabbits turn afterward their head so that the preserved eye should be directed forward. Besides, both ears act in a vicarious manner for the lost eye; the ear of the blind side playing constantly forward and that of the seeing side in a backward direction. At the autopsy of the full-grown animal the optic nerve belonging to the destroyed retina is found atrophied, gray and transparent (instead of being white like the one of the existing retina), which atrophy can be traced in the tractus opticus on the opposite side of the chiasma.

There is also atrophy of the corresponding anterior prominence of the corpora quadrigemina.

When both eyes are enucleated, the rabbits present a very characteristic appearance. Both ears act very vividly in all directions, in a vicarious manner for the eyes, especially if the animals are brought into a new place, into new surroundings.

The ears of the blind rabbits become more developed, and the muscles and nerves increased in size.

Both nervi optici, tractus optici, and anterior prominences of the corpora quadrigemina are in the highest degree atrophied and transparent.

Gudden was unable to ascertain with exactness the effect of the atrophy of the optic organs upon the hemispheres in rabbits; he therefore instituted the following experiments upon pigeons, in which the sight is the predominant sense:—

He enucleated one eye in a newly-hatched pigeon, and made the autopsy after eight weeks. There was found a strikingly marked atrophy of the corresponding optic nerve, of the corresponding half of the corpora bigemina (lobi optici), and of the corresponding hemisphere. The effect upon the psychical development of the pigeon when both eyes are enucleated is quite different and immensely greater than in rabbits. The grown-up pigeons remain in a condition which may be called idiocy. At the autopsy (after 8 weeks) only traces of the optic nerves can be found; the lobi optici and the hemispheres are greatly arrested in their development. The brain of the operated pigeons compared with that of the non-operated pigeons, hatched contemporaneously, of the same pair, and killed simultaneously, shows the following difference in weight: the brain of the non-operated pigeon weighed 1.84 grammes; the brain of the blinded on one side, 1.73 grm.; and that of the completely blind one weighed 1.39 grm. These differences are still more striking on the illustrations accompanying Gudden's researches.

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Mechanism of Production of Symptoms in Diseases of the Brain.
Morbid Influences of the Nervous System on Organic Functions.
Physiological and Pathological Proofs of Attraction of Blood by Tissues.
Amaurosis and Deafness in Diseases of the Brain.
Rational Treatment of Poisoning by Organic Substances.
On the Various Kinds of Hemiplegia.
On Counter-Irritation: Its Importance and Rational Use.
Physiology and Pathology of Epileptiform Affections.
On Pneumonia and other Lung Affections in Diseases of the Brain.
On Reflex Paralysis and other Affections produced by a Reflex Influence.
Analogies and Differences between several Remedies (Belladonna, Digitalis, the Ergot of Rye, and the various Bromides).
Artificial Epilepsy in Animals, and what it Teaches for the Treatment of Epilepsy in Man.
On Transfusion of Blood: New Methods and Proper Conditions for its Use.
On Differences between Americans and Europeans, as regards Diseases and Power of Resisting Injuries.